SEARCH FOR DIRECT TOP SQUARK PAIR PRODUCTION IN FINAL STATES WITH TWO LEPTONS OF OPPOSITE CHARGE

Moriond Electroweak – Young Scientist Forum

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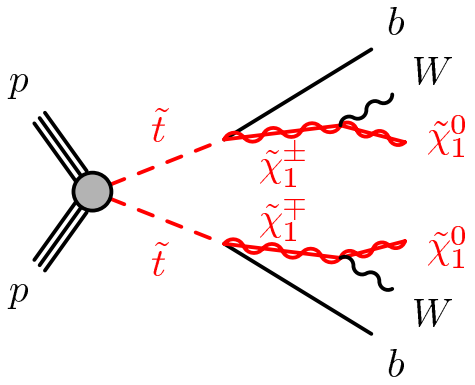
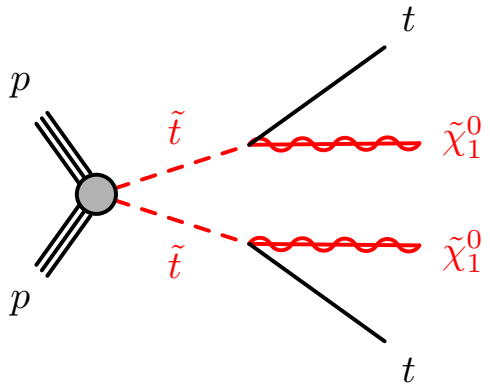
The Physics Case

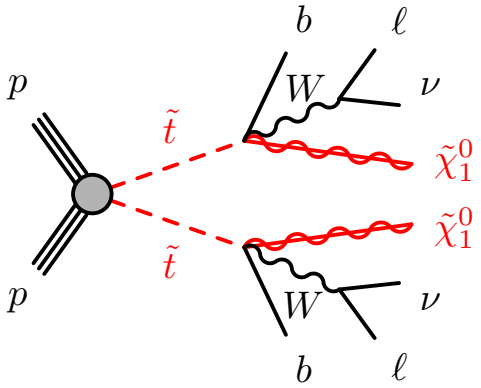
Natural SUSY requires the ***top* squarks** to be not too heavy, up to O(1 TeV).



$$\tilde{t}\tilde{t} \rightarrow b\tilde{\chi}^{\pm}b\tilde{\chi}^{\mp}$$



$$\tilde{t}\tilde{t} \rightarrow t\tilde{\chi}_1^0 t\tilde{\chi}_1^0$$



$$\tilde{t}\tilde{t} \rightarrow bW\tilde{\chi}_1^0 bW\tilde{\chi}_1^0$$

Target the final states containing **exactly two** isolated, high-p_T **leptons**

CUT & COUNT

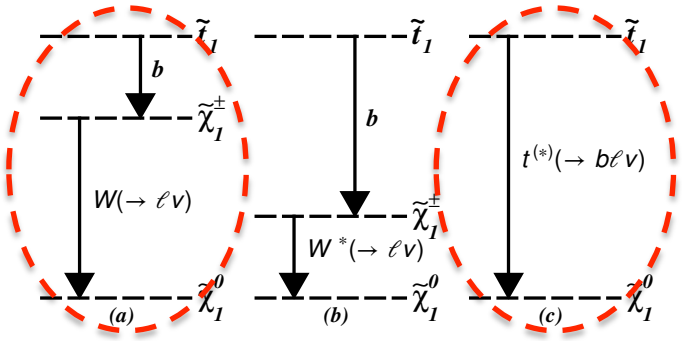
1. **Leptonic m_{T2}**: b + $\tilde{\chi}^{\pm}$, 3-body decay
2. **Hadronic m_{T2}**: b + $\tilde{\chi}^{\pm}$

MVA

3. **MVA**: targets t + $\tilde{\chi}_1^0$

NEW!!!
arXiv:1403.4853

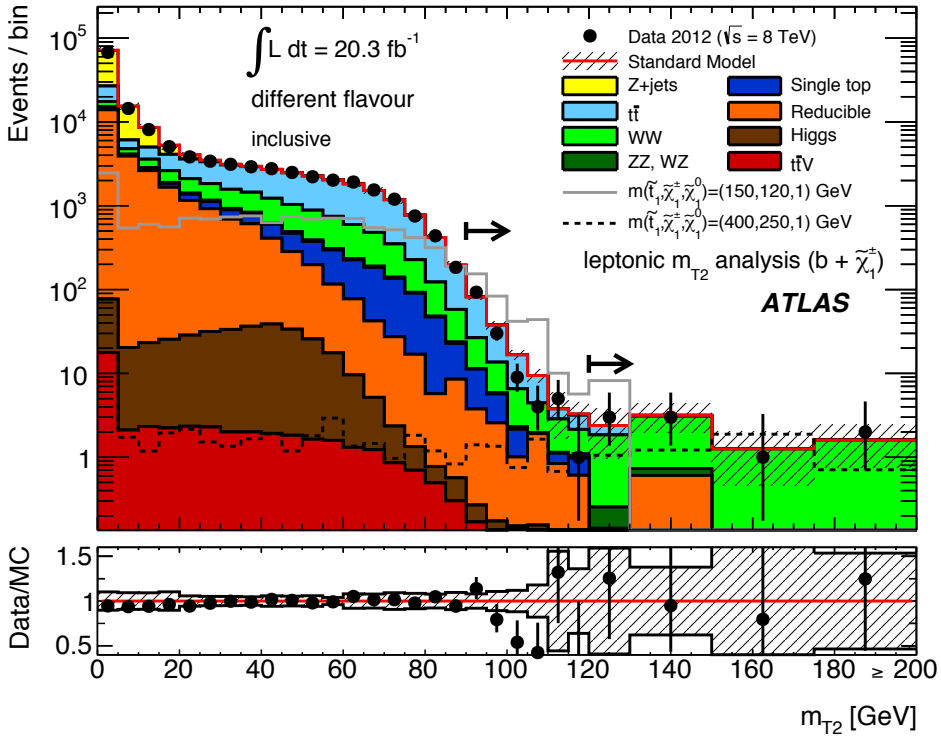
Leptonic m_{T2}



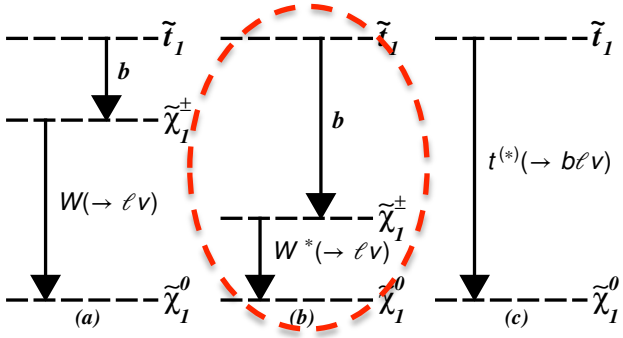
LEPTONIC STRANSVERSE MASS

$$m_{T2}^{\ell\ell}\left(\vec{p}_T^{\,\ell_1},\vec{p}_T^{\,\ell_2},\vec{\not{p}}_T\right)=\min_{\vec{q}_T^{\,1}+\vec{q}_T^{\,2}=\vec{\not{p}}_T}\left\{\max\left[m_T\left(p_T^{\ell_1},\vec{q}_T^{\,1}\right),m_T\left(p_T^{\ell_2},\vec{q}_T^{\,2}\right)\right]\right\}$$

MAIN DISCRIMINANT: m_{T2} computed from the momenta of the two leptons.



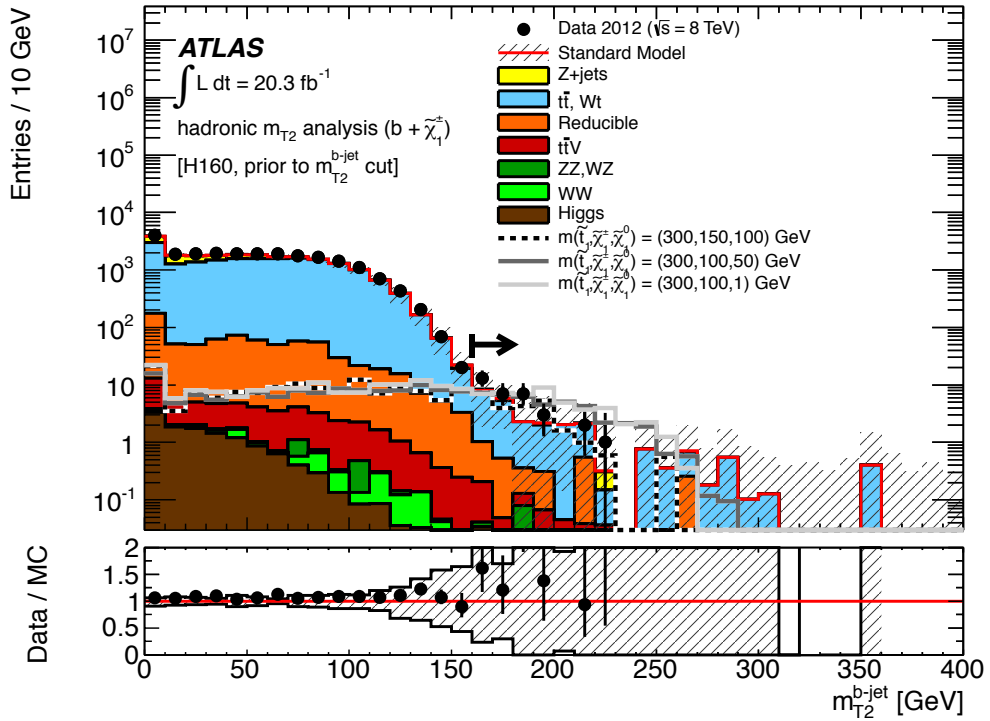
Hadronic m_{T2}



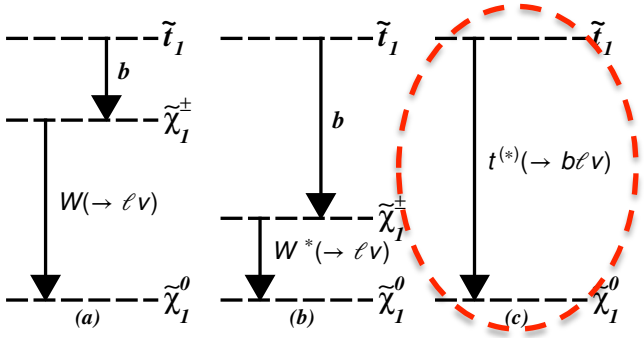
HADRONIC STRANSVERSE MASS

$$m_{T2}^{b-jet}\left(\vec{p}_T^{\,b_1},\vec{p}_T^{\,b_2},\vec{\not{p}}_T\right)=\min_{\vec{q}_T^{\,1}+\vec{q}_T^{\,2}=\vec{\not{p}}_T}\left\{\max\left[m_T\left(p_T^{b_1},\vec{q}_T^{\,1}\right),m_T\left(p_T^{b_2},\vec{q}_T^{\,2}\right)\right]\right\}$$

MAIN DISCRIMINANT: m_{T2} computed from the momenta of the two b-jets.



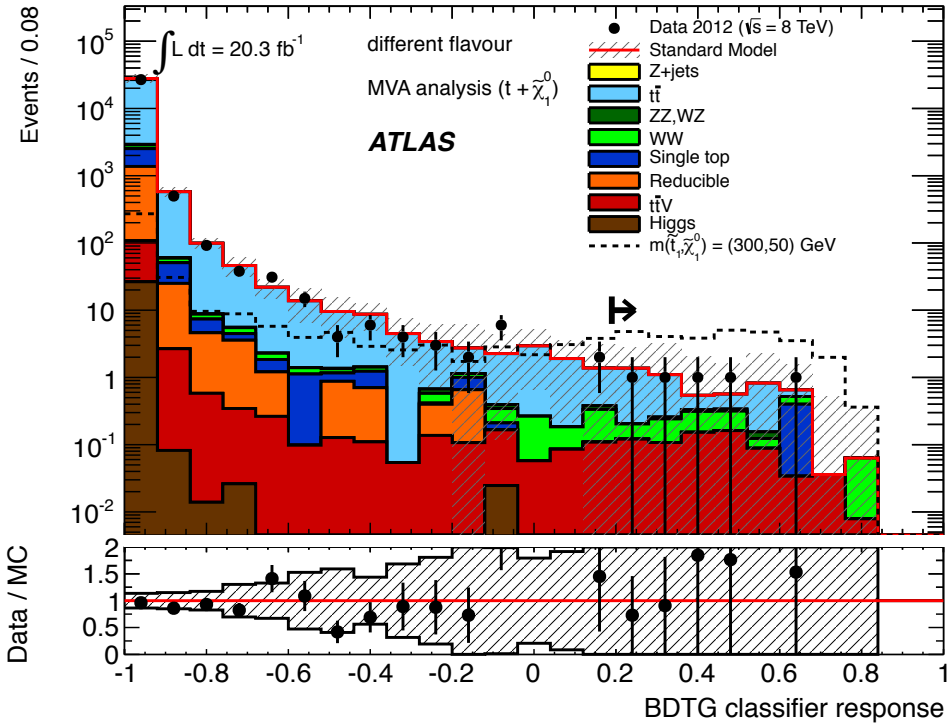
Multivariate Analysis



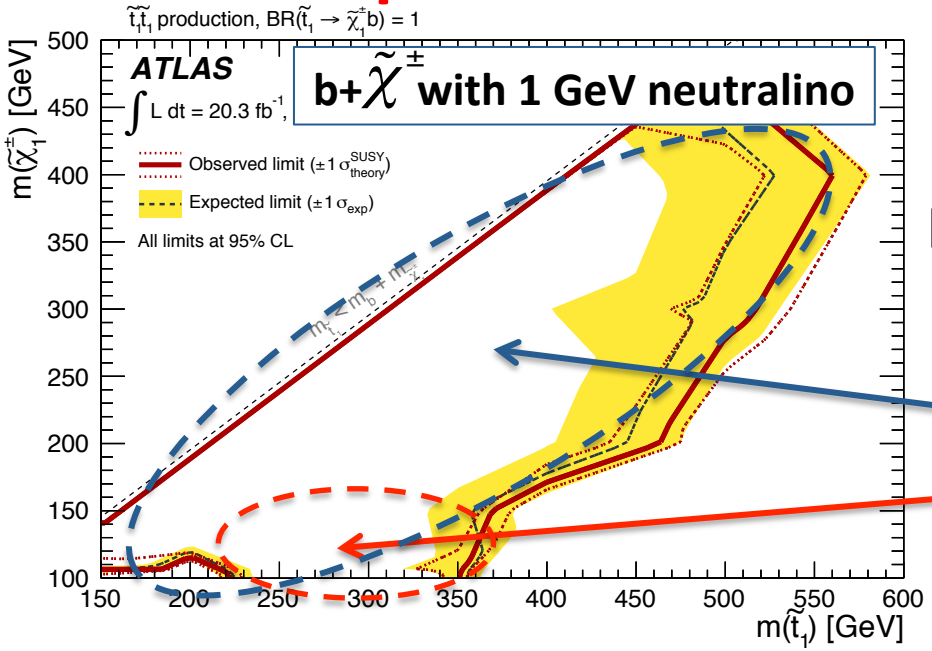
MVA discriminant (BDTG) based on:

E_T^{miss}, $m_{\ell\ell}$, m_{T2},

$\Delta\phi(\ell,\ell)$, $\Delta\theta(\ell,\ell)$, $\Delta\phi(\ell,E_T^{miss})$ and $\Delta\phi(j,\ell)$

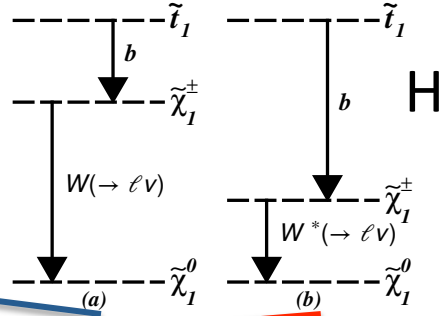


Simplified model interpretation



LEPTONIC

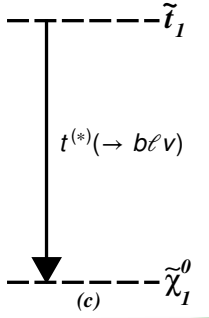
m_{T2}

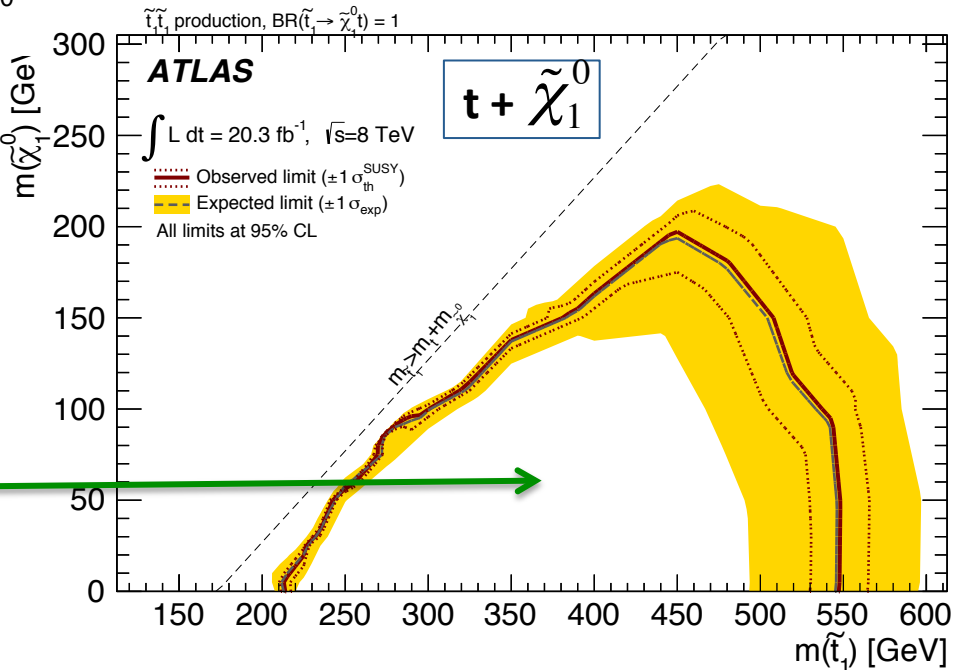


HADRONIC

m_{T2}

MVA





Conclusions

A comprehensive set of searches for a pair of *top squarks* decaying into two lepton final states has been performed using 20.3 fb^{-1} of *pp* collision data at $\sqrt{s}$ = 8TeV.

- Paper submitted to JHEP, **arXiv:1403.4853**
- The number of observed events has been found to be consistent with the Standard Model expectation.

- Limits have been set in many simplified models targeting b+$\tilde{\chi}^{\pm}$ or t+$\tilde{\chi}_1^0$ decays for different assumptions on the mass hierarchy *top squark - lightest chargino - lightest neutralino*.

BACKUP

Stransverse mass

This is a generalized transverse mass for **systems with two invisible particles**

SM EXAMPLE: top pair dileptonic decay

The lepton-neutrino transverse mass obeys on both sides:

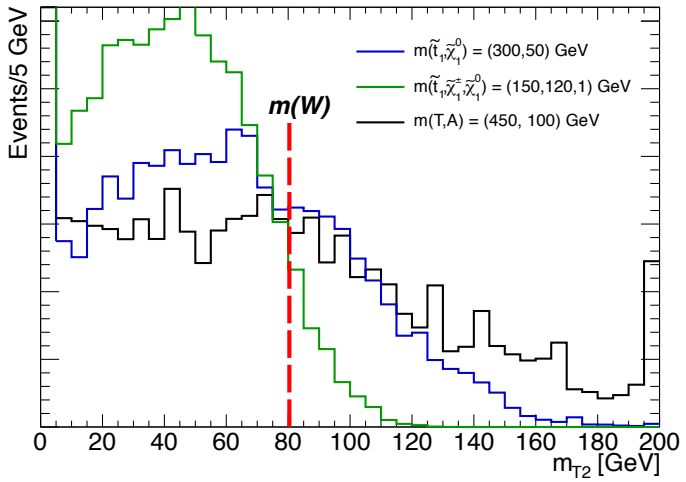
$$m_T(l,\nu) = \sqrt{2\,p_T(l)\,p_T(\nu)\left[1-\cos(\varphi_l-\varphi_\nu)\right]} < m(W)$$

$$\max\left[m_T\left(p_T^1,\vec{q}_T^{\,1}\right), m_T\left(p_T^2,\vec{q}_T^{\,2}\right)\right] < m(W)$$

- The direction of the two neutrinos is unknown, but it's possible to **try all possibilities and take the minimum**.

$$m_{T2}\left(\vec{p}_T^{\,1},\vec{p}_T^{\,2},\not{\vec{p}}_T\right) = \min_{\vec{q}_T^{\,1}+\vec{q}_T^{\,2}=\not{\vec{p}}_T}\left\{\max\left[m_T\left(p_T^1,\vec{q}_T^{\,1}\right), m_T\left(p_T^2,\vec{q}_T^{\,2}\right)\right]\right\}$$

- **m_{T2} < m(W)** for *top pairs*, *Wt* and *WW*.



SIGNAL can extend to higher values, depending on the mass splitting of the involved particles

- A cut and count approach is sensitive to large $\Delta m\left(\tilde{t}_1,\tilde{\chi}_1^0\right)$ or $\Delta m\left(\tilde{\chi}_1^\pm,\tilde{\chi}_1^0\right)$

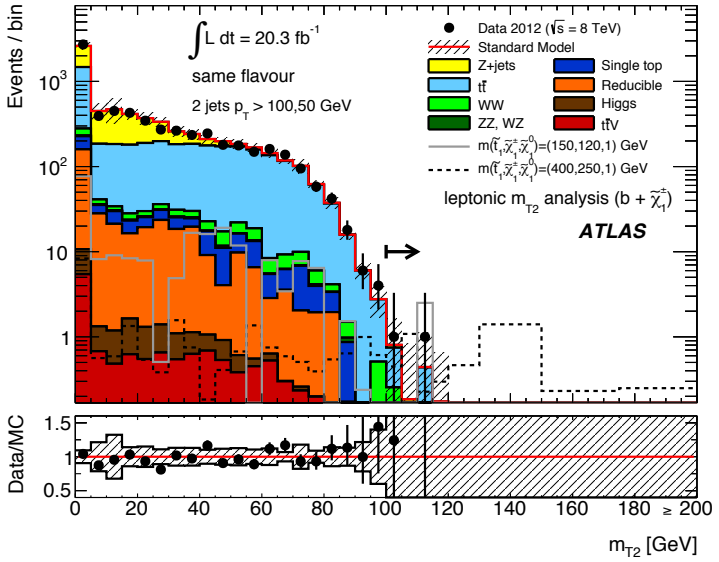
Common analysis strategy

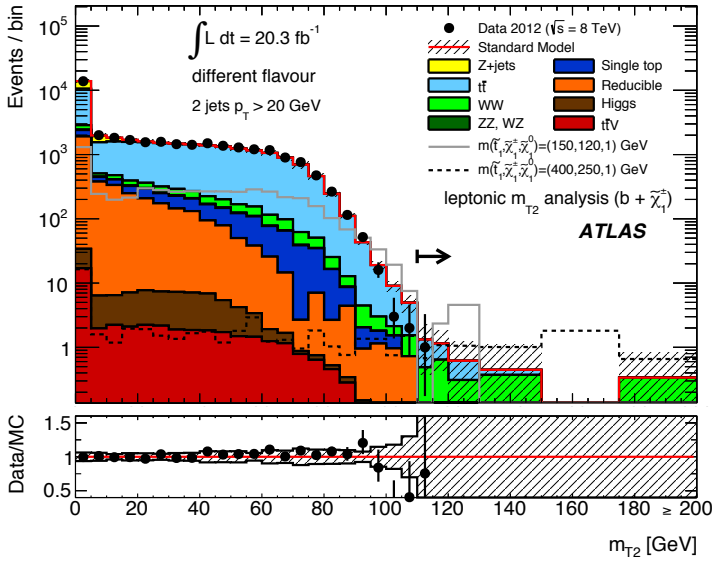
All the three analyses presented share a common approach:

- Define a *Signal Region* (SR) based on signal kinematic features
- Estimate the Standard Model processes in the SR:
  - **Data-driven** reducible backgrounds (QCD multijet backgrounds)
  - **Semi data-driven** major irreducible backgrounds
    - Define a *control region* (CR) for each of the backgrounds
    - Normalise MC yields to data
    - Apply transfer factor from CR to SR
  - Minor backgrounds are taken from **MC simulation** only
- When possible, check background estimation against data in *Validation Regions* (VR)
- Look at the observed data in the SR

Leptonic m_{T2}

SR	L90	L100	L110	L120
leading lepton p_{T} [GeV]	> 25			
$\Delta\phi_j$ [rad]	> 1.0			
$\Delta\phi_{\mathrm{b}}$ [rad]	< 1.5			
m_{T2} [GeV]	> 90	> 100	> 110	> 120
Leading jet p_{T} [GeV]	-	> 100	> 20	-
Second jet p_{T} [GeV]	-	> 50	> 20	-
$\Delta m(\tilde{t}_1, \tilde{\chi}_1^{\pm})$	small	large	moderate	small
$\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0)$	moderate	large	moderate	large





Hadronic m_{T2}

SR	H160
b-jets	$= 2$
Leading lepton p_{T} [GeV]	< 60
m_{T2} [GeV]	< 90
$m_{\mathrm{T2}}^{b-\mathrm{jet}}$ [GeV]	> 160
$\Delta m(\tilde{t}_1, \tilde{\chi}_1^{\pm})$	large
$\Delta m(\tilde{\chi}_1^{\pm}, \tilde{\chi}_1^0)$	small

Multivariate Analysis

Require: ≥2 jets (lead p_T > 50 GeV)
m_{eff} > 300 GeV

Then apply four sets of cuts:

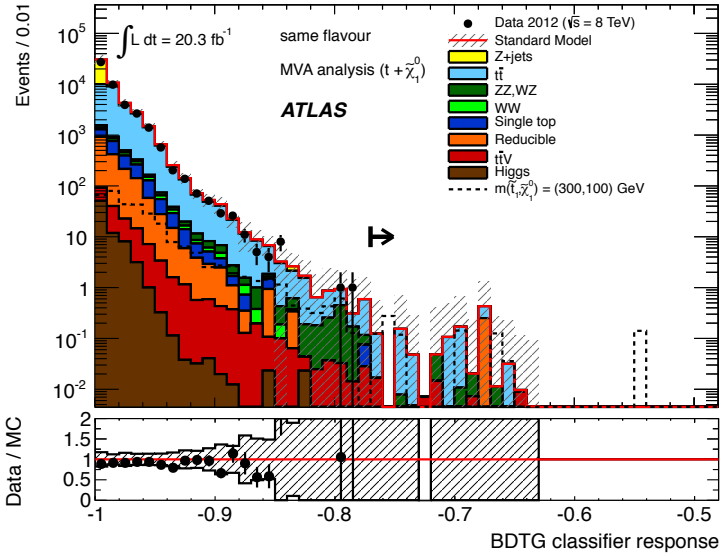
(C1) E_T^{miss} > 50 GeV

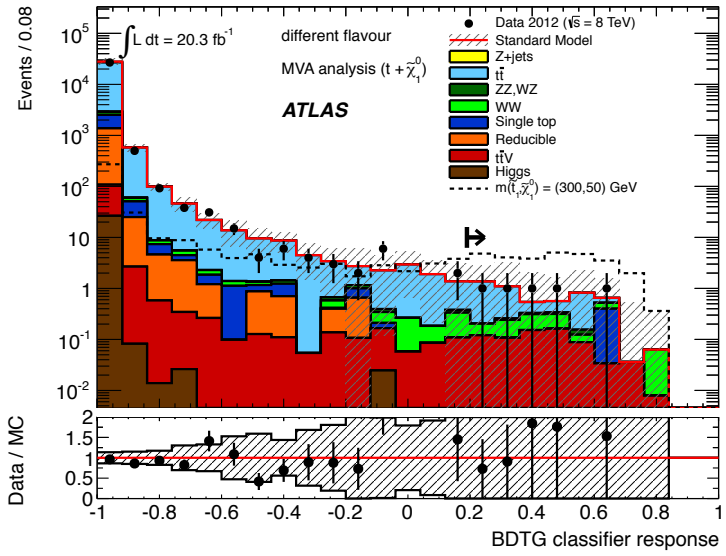
(C2) E_T^{miss} > 80 GeV

(C3) E_T^{miss} > 50 GeV and $p_T(l_1)$ > 50 GeV

(C4) E_T^{miss} > 50 GeV and $p_T(l_1)$ > 80 GeV

- 9 SRs are defined applying a final selection on a MVA discriminant.
- The main background (top pair) is normalized in CRs

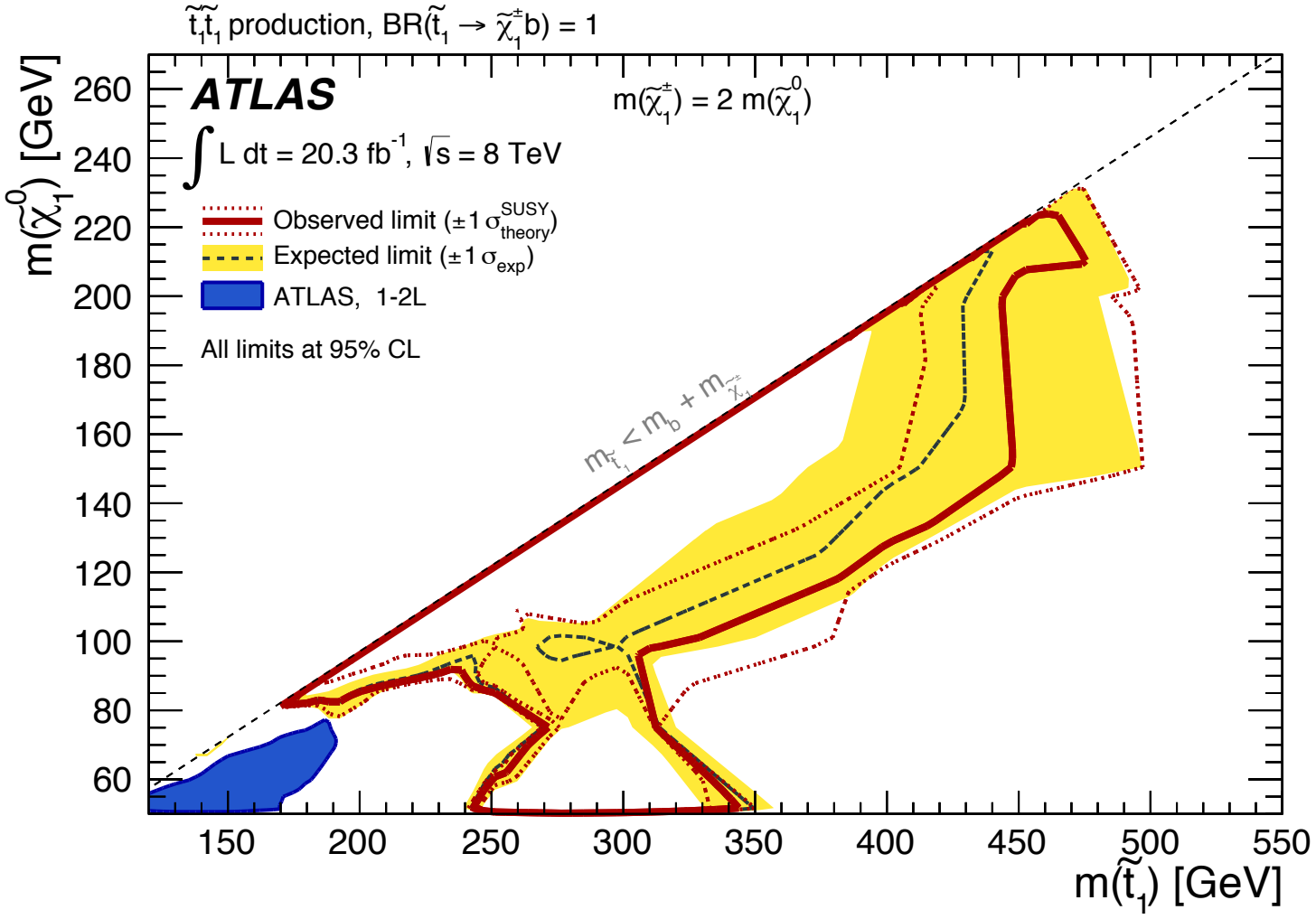




Systematic Uncertainties

Experimental Uncertainties:	JES, JER, SoftTerm, pile-up, b-tagging, JVF, etc..
Top generator:	comparison between MC@NLO and Powheg+Jimmy
Top parton shower:	comparison between Powheg+Pythia and Powheg+Jimmy
Top ISRFSR:	AcerMC dedicated samples
Diboson generator:	compare Powheg vs Sherpa samples
Fake lepton:	limited statistics of the CRs discrepancy of the fake rate estimated from the different QCD control samples
Z+jets generator:	compare Sherpa vs Alpgen samples
top + Wt interference:	compare MC@NLO with AcerMC

Simplified model interpretation



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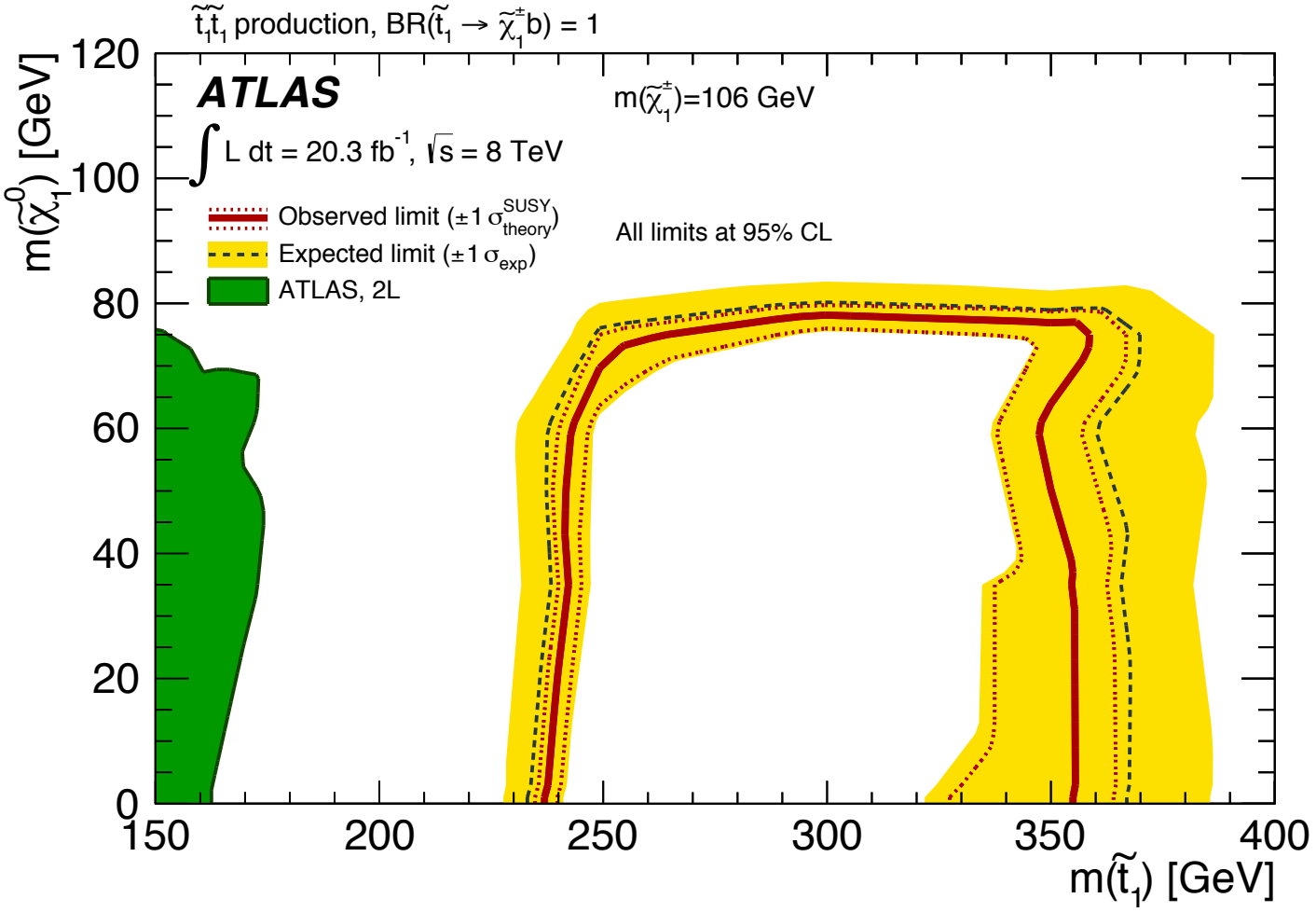

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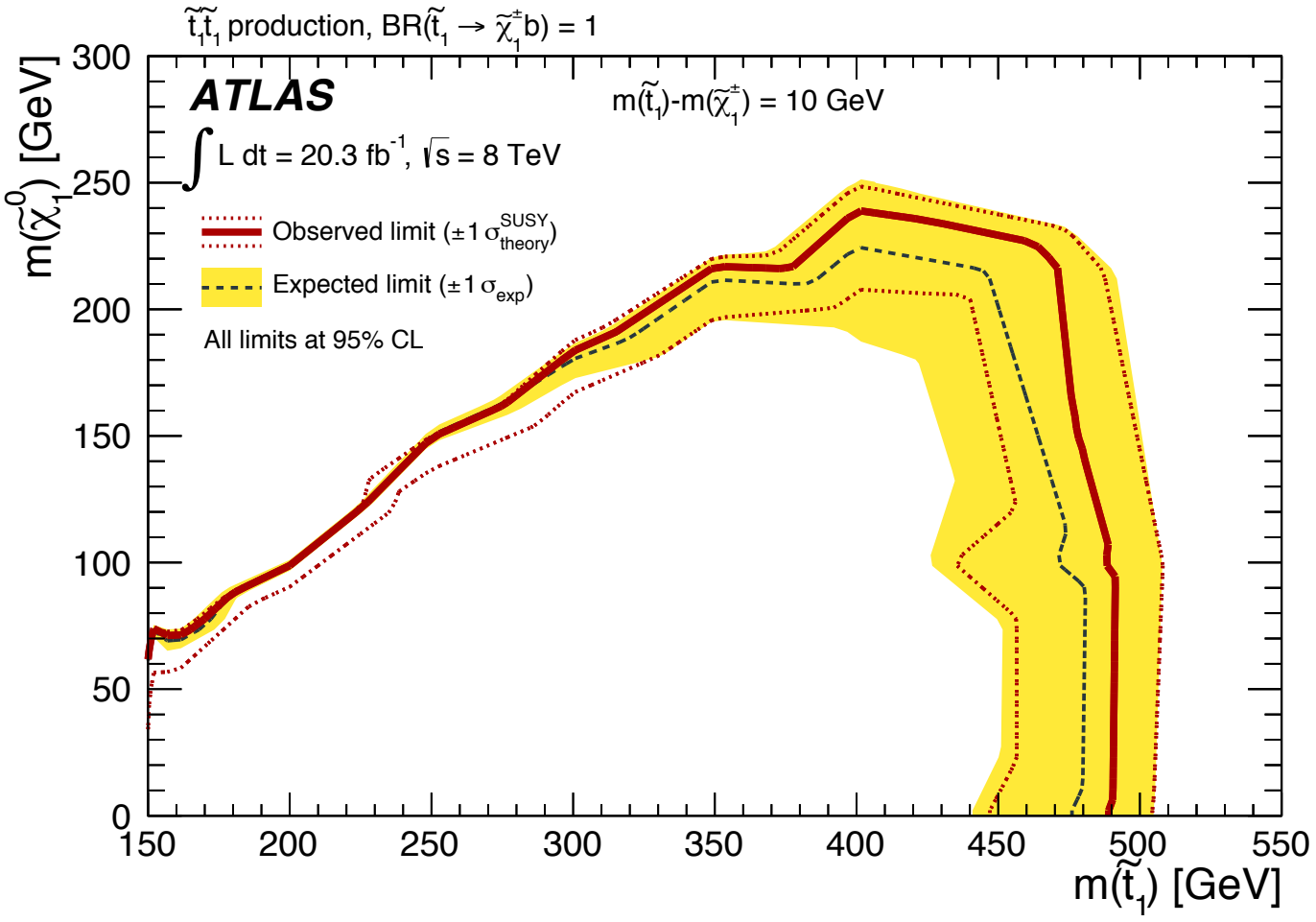

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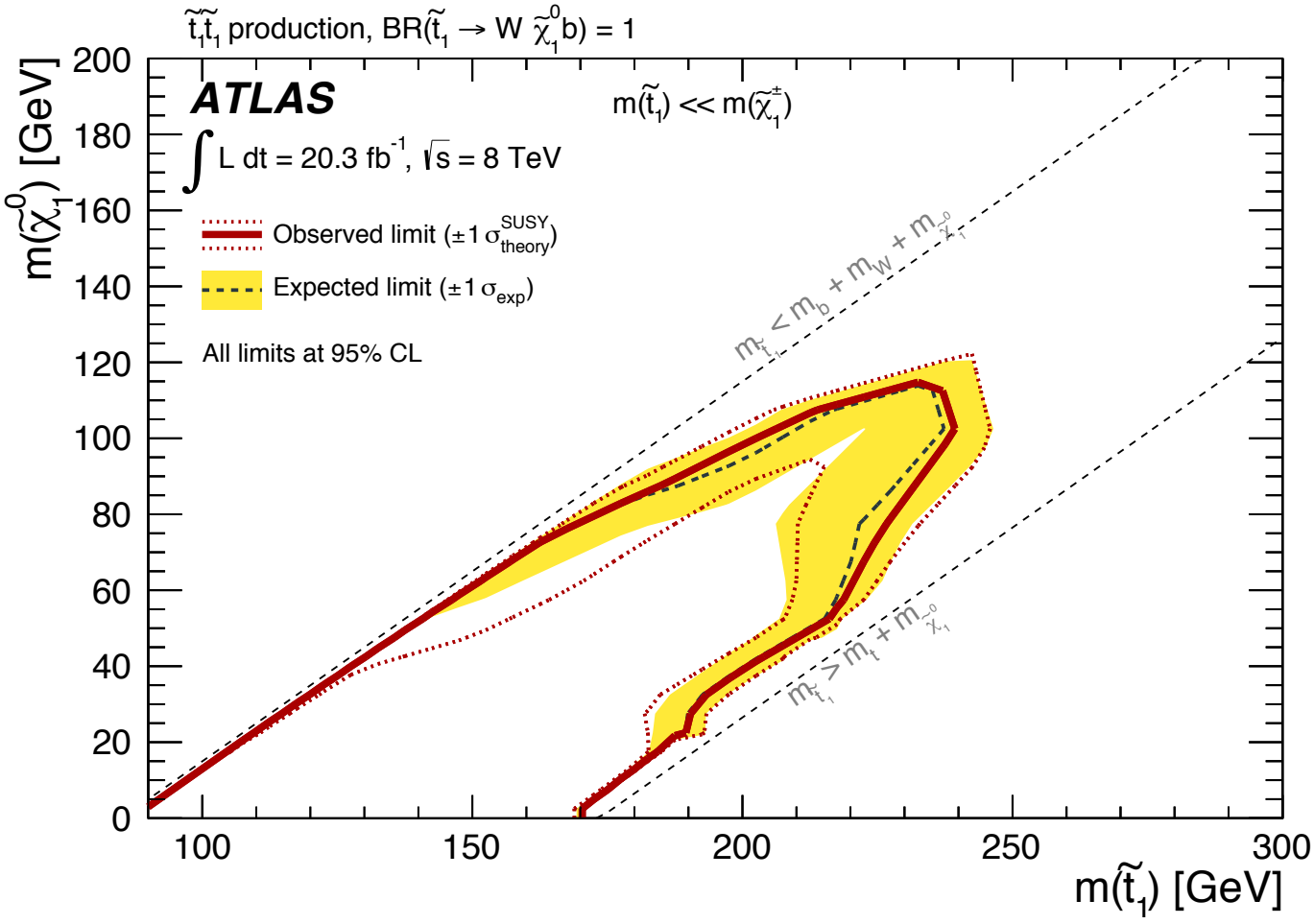

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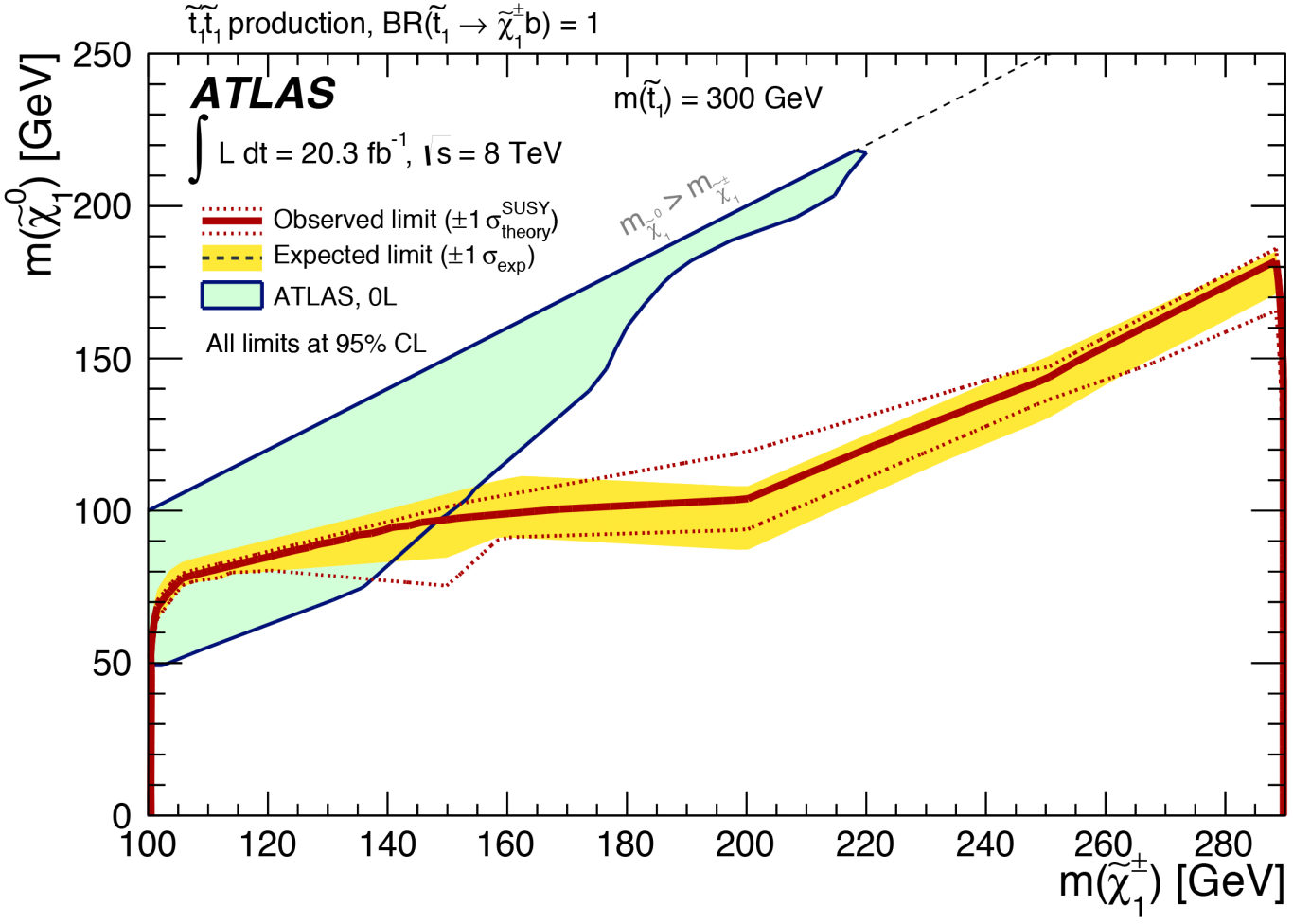

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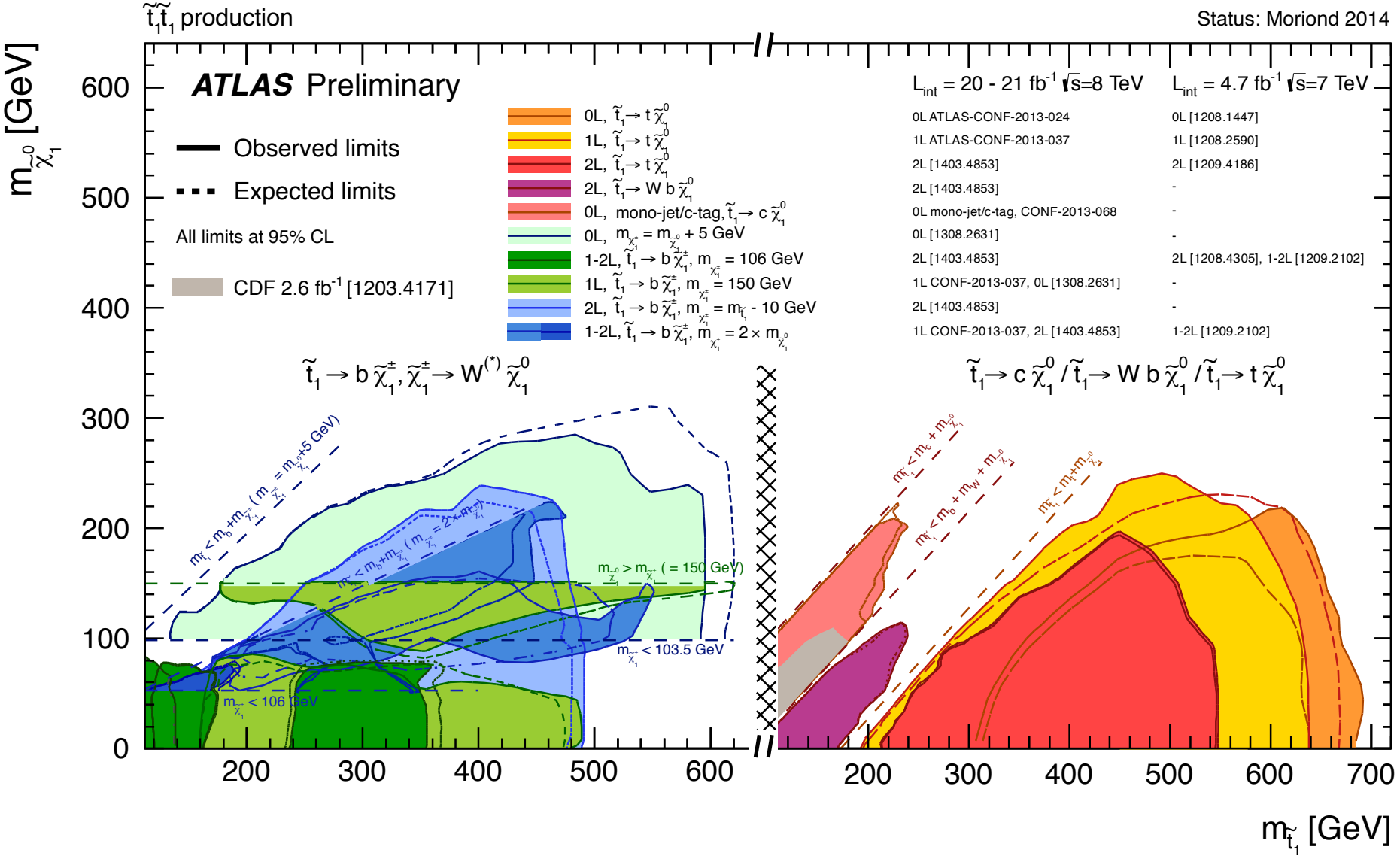

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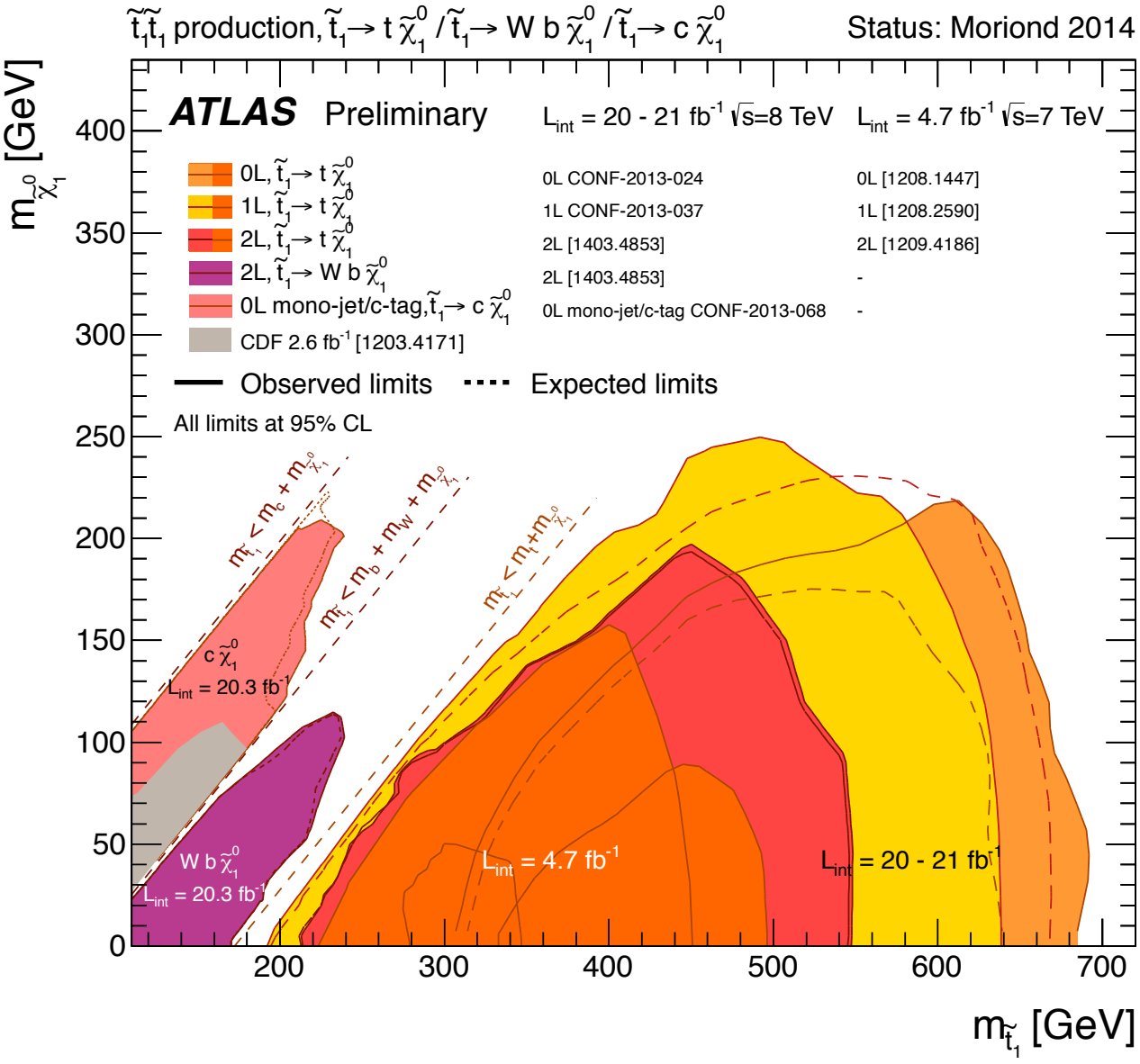

Simplified model interpretation